Jurnal Teknologi

Full paper

Effect of Water on Electrical Properties of Refined, Bleached, and Deodorized Palm Oil (RBDPO) as Electrical Insulating Material

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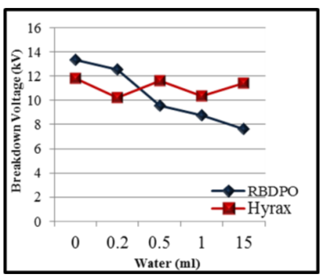
Article history

Received :15 February 2013
Received in revised form :
10 June 2013
Accepted :16 July 2013

Graphical abstract



Breakdown voltage of RBDPO and Hyrax oil due to water amount

Abstract

This paper describes the properties of refined, bleached, deodorized palm oil (RBDPO) as having the potential to be used as insulating liquid. There are several important properties such as electrical breakdown, dielectric dissipation factor, specific gravity, flash point, viscosity and pour point of RBDPO that was measured and compared to commercial mineral oil which is largely in current use as insulating liquid in power transformers. Experimental results of the electrical properties revealed that the average breakdown voltage of the RBDPO sample, without the addition of water at room temperature, is 13.368 kV. The result also revealed that due to effect of water, the breakdown voltage is lower than that of commercial mineral oil (Hyrax). However, the flash point and the pour point of RBDPO is very high compared to mineral oil thus giving it advantageous possibility to be used safely as insulating liquid. The results showed that RBDPO is greatly influenced by water, causing the breakdown voltage to decrease and the dissipation factor to increase; this is attributable to the high amounts of dissolved water.

Keywords: Refined bleached deodorized palm oil (RBDPO); electrical properties; chemical properties; physical properties

Abstrak

Kertas kerja ini menerangkan sifat-sifat halus, putih, minyak sawit dinyahbau (RBDPO) untuk digunakan sebagai penebat cecair. Terdapat beberapa ciri-ciri penting seperti kerosakan elektrik, faktor pelesapan dielektrik, graviti tentu, takat kilat, kelikatan dan mencurahkan titik RBDPO diukur dan dibandingkan dengan minyak mineral yang sebahagian besarnya digunakan sebagai bahan dalam transformer kuasa penebat. Keputusan eksperimen sifat elektrik mendedahkan kerosakan voltan purata sampel RBDPO tanpa menambah air pada suhu bilik menjadi 13,368 kV, namun disebabkan kesan air, voltan pecahan menurun lebih tinggi daripada minyak mineral komersial (Hyrax). Titik kilat RBDPO adalah sangat tinggi berbanding dengan minyak mineral yang memberikan kemungkinan untuk digunakan dengan selamat sebagai bahan penebat. Walau bagaimanapun, perkara pour yang RBDPO adalah tinggi berbanding dengan minyak mineral. Keputusan yang diperolehi menunjukkan bahawa RBDPO banyak dipengaruhi oleh air, di mana menyebabkan kerosakan voltan untuk mengurangkan pelesapan dan faktor untuk meningkatkan kerana ia boleh membubarkan jumlah yang tinggi daripada air.

Kata kunci: Ditapis luntur dinyahbau minyak sawit (RBDPO); sifat-sifat elektrik; sifat-sifat kimia; sifat-sifat fizikal

1.0 INTRODUCTION

Liquid insulations are widely used in high voltage systems such as power transformer where it provides electrical insulation, suppress corona and arcing and acts as a coolant to prevent the transformer from overheating[1]. The insulating oil must possess high dielectric strength, high thermal stability, low dielectric losses and reasonable economical prices.

Petroleum-based mineral oils readily meet almost all the characteristics of insulating oils and so they are in common use as the liquid insulator in power transformer[1]. However, mineral oil has negative impact to the environment, contaminating the soil and water, whenever there are cases of accidental transformers fires, explosions or tank raptures. Furthermore, mineral oil is from a fossil fuel source that is exhaustible and depleting thereby raising concern that it may not meet the needs of future generations. Therefore, due to the concern of community towards the environment, many researches are been conducted to address the environmental challenge posed by the use of mineral oil in transformers.

Many type of oil have been proposed as potential alternatives to mineral oil and they include CPKO (crude palm kernel oil), CPO (crude palm oil), CCO (crude coconut oil) and RBDPO (refined, bleached and deodorized palm oil)[2]. Most of the researchers have found that RBDPO has a potential to be an alternative insulating material since it has good dielectric characteristics such as high dielectric strength[2, 6, 23].

The relationship between insulation failure and moisture content is shown in Table 1 and 2. They show that the main factors for the failure of power transformer, such as lightning surge, line surge and insulation failure happened when there is moisture content in the transformer insulation. Although the failure caused by the moisture is low in percentage, it may affect the operation of the transformer and increase the maintenance cost. The moisture category includes failures caused by leaking pipes, leaking roofs, water entering the tanks through leaking bushings or fittings, and confirmed presence of moisture in the insulating oil.[3]

Table 1 Causes of transformer failures[3]

Cause of Failure	1975	1983	1998
Lightning surge	32.3%	30.2%	12.4%
Line surge/external short circuit	13.6%	18.6%	21.5%
Poor workmanship manufacture	10.6%	7.2%	2.9%
Deterioration of insulation	10.4%	8.7%	13%
Overloading	7.7%	3.2%	2.4%
Moisture	7.2%	6.9%	6.3%
Inadequate maintenance	6.6%	13.1%	11.3%
Sabotage, Malicious mischief	2.6%	1.7%	0%
Loose connection	2.1%	2.0%	6.0%
All others	6.9%	8.4%	24.2%

Table 2 Cause of failures and total paid[3]

Cause of Failure	Number	Total Paid [$]
Insulation failure	24	149,967,277
Design/material/workmanship	22	64,696,051
Unknown	15	29,776,245
Oil Contamination	4	11,836,367
Overloading	5	8,568,768
Fire/explosion	3	8.045,771
Line surge	4	4,959,691
Improper maint/operation	5	3,518,783
Flood	2	2,240,198
Loose connection	6	2,186,725
Lightning	3	657,935
Moisture	1	175,000
Others	94	286,628,811

■2.0 EXPERIMENTAL

2.1 Sample

In this experiment, RBDPO and mineral oil (Hyrax) are used as samples. In order to observe the effect of water to the insulating liquid, distilled water has been added into both oil types at 0.2, 0.5, and 1.0 ml by volume per sample prepared. The use of distilled water is akin to the water that has been condensed in actual power transformer.

In this research, water was added into the insulation oil by using a small 3 ml syringe. A magnetic stirrer with hotplate was used for mixing water in the oil. The temperature was maintained in range of 45 to 50ºC to avoid vaporization of water and the oil was stirred for 3 hours [12, 13]. The equipment used is shown in Figure 1.

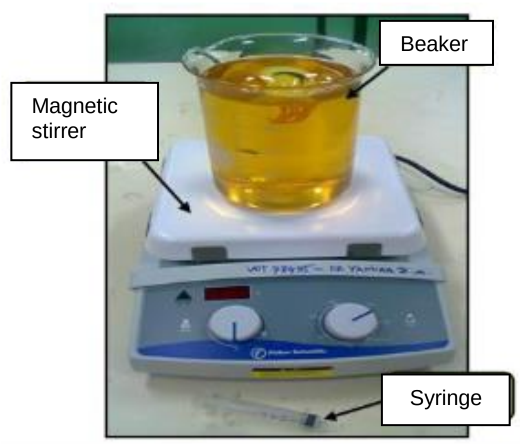


Figure 1 Adding moisture into oil

2.2 Breakdown Voltage

Breakdown voltage test is a part of electrical characteristic to measure the strength of the insulating material when injected with a high voltage. The electrode of the test cell is adjusted to 2.5 mm according to the IEC standard (IEC 60156)[12]. The test cell was connected to high voltage and the voltage was slowly and cautiously raised by 2kV/s until breakdown occurs.

Figure 2 shows the test cell that was used for breakdown test while the actual experimental setup for breakdown voltage test is shown in Figure 3.

All observed data from the dielectric property measurements which include the breakdown voltage and dielectric dissipation factor (tanδ) are collected and analyzed to compare the dielectric characteristics of both Hyrax oil and RBDPO.

Figure 2 Filling the test cell with test sample

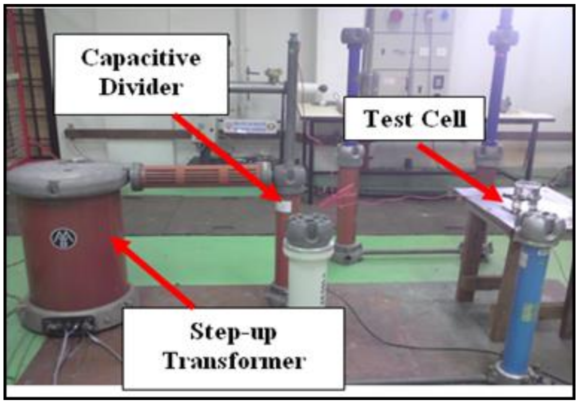


Figure 3 Experimental setup for breakdown voltage test

2.3 Dissipation Factor

The dissipation factor of each sample was tested based on BS 5737-Measurement of relative permittivity, dielectric dissipation factor and dc resistivity of insulating liquids[7]. Figure 4 shows the equipment for dissipation factor measurement. The test cell is injected with increasing steps of 2.0 kV voltage supply. The dissipation factor value is recorded.

Figure 4 Equipment for dissipation factor measurement

3.0 RESULTS AND DISCUSSION

The results of the physical and chemical properties of Hyrax oil and RBDPO are shown in Table 3. The standard properties for Hyrax from commercial technical specification are shown in Table 4.

According to the result, Hyrax oil meets the requirement of the standard compared to the RBDPO. This shows that Hyrax oil is a better liquid insulating material. This is the reason why Hyrax oil is used widely in the whole world as transformer oil. However, the RBDPO is a new liquid insulating material that is environment friendly compared to the Hyrax oil. This indicates the prospect of RBDPO to be further processed to get better dielectric properties and meet all requirements to be used as liquid insulating material.

Table 3 Physical and chemical properties of RBDPO and Hyrax oil

Properties	Standard value (Hyrax)	RBDPO	Hyrax
Density at 150ºC [kg/m^3]	890	915.5	880.5
Viscosity [cSt], 40 ºC	<16.5	47.64	10.16
Viscosity [cSt], 100 ºC	<16.5	12.59	3.287
Pour point [ºC]	-30 (max)	9	>-30
Flash point [ºC]	140 (min)	320	170
Water content [ppm]%	-	0	0

3.1 Breakdown Voltage

Figure 5 shows the breakdown voltages for RBDPO and Hyrax oil at different water contents. The breakdown voltage of RBDPO decreases as the water content in the sample increases. However, the breakdown results of Hyrax oil gives an unexpected pattern where the breakdown voltage increased when 0.5 ml of water was added into the oil and decreased when 1.0 ml water was added to the oil.

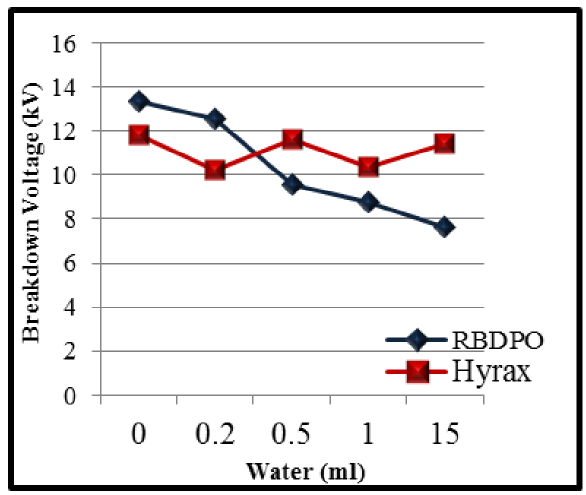


Figure 5 Breakdown voltages of RBDPO and Hyrax oil

According to Julliard [4], the creation of emulsion might be the reason for the increasing of breakdown voltage since the emulsion has other physic-chemical properties such as the chemical bound of water in oil mixture. The breakdown voltage of Hyrax oil started at 11.79 kV because it was affected by the environment during the sample preparation. The sample exposed directly to the air. This is may be attributable to the fact that mineral insulating oil is very sensitive to the environment; thus it needs a handling and proper storage such a dark glass bottle.

3.2 Tan δ

Figure 6 shows the dissipation factor (tan δ) of the sample of RBDPO and Hyrax oil for different amounts of water content. The result clearly shows that the sample of RBDPO has a low dissipation factor compared to the mineral oil sample. The dissipation factor of RBDPO increases as the amount of water content increases. This pattern of increase for the dissipation factor shows correlation with the pattern of the breakdown voltage.

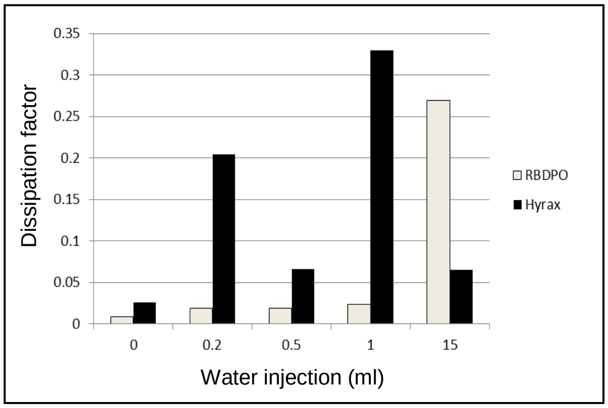


Figure 6 Tan δ of RBDPO and Hyrax oil

4.0 CONCLUSION

This study has been carried out to study a new insulating oil to be used as insulation material that can replace the existing petroleum-based transformer oil. During this studies and experimental work in investigating the electrical properties of both insulation oils, appropriate standards have been referred to. The study describes the experiment on the dielectric properties of insulating oils and their effect to the moisture. This was done in order to rate the dielectric properties of proposed alternative insulating oil, a palm based oil (RBDPO), and a widely used mineral oil. The conclusions are summarized below:

- The use of mineral oil as transformer oil gives negative impact when there is leakage during operation; it can contaminate the environment as it is less biodegradable. Vegetable oil has been acknowledged as a good alternative material for transformer oil due to its good biodegradable characteristic, low pour point, high flash point, and high solubility.
- Alternative oil has may be found in palm based oils they have high potential to be good insulating liquid for transformer due to its good characteristic such as high flash point.
- The results show that the properties of RBDPO were greatly influenced by moisture where the breakdown voltage decreases dramatically compared to the existing mineral oil (Hyrax).
- However, although RBDPO has not satisfied the requirement needed in electrical properties as good insulation oil, it is environmentally friendly compared to mineral oil. Further research is needed to improve the characteristics of RBDPO used in insulating material.

Acknowledgement

The authors would like to thank Ministry of Higher Education Malaysia (MOHE) under research Grant VOT No: 78495 and Malaysia Palm Oil Board (MPOB) for providing palm oil sample. This Research partly supported by UTM Research University Grant under Vot. Q.J130000.2523.00H19.

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